

# Power System Loss Minimization Using Optimal Placement of UPFC Given by Bat Algorithm

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**Abstract-** In this paper a heuristic method for minimizing active power loss of the power system using Unified Power Flow Controller is proposed. The novelty of the proposed method is to use the Bat algorithm to find optimal location of UPFC. Bat algorithm provides superior searching ability. Here, the bat algorithm optimizes location of UPFC when the generator outage occurs in the system. Generator outage affects the power flows, bus voltages, power loss, real and reactive power. By placing The UPFC at the optimal location, performance of the system is analyzed. The proposed method is implemented in the MATLAB/Simulink platform and tested on IEEE 30 bus standard bench mark system. The proposed method's performance is evaluated by comparison with different conditions. The comparison results proved the effectiveness of the proposed method and confirm its potential to minimize power loss.

**Keywords:** Bat algorithm, Power loss, UPFC.

## 1. INTRODUCTION

The quantity of electrical power transmitted safely by a transmission system is restricted [1]. Electrical power utilities through the world are working under pressured, in order to maximize total capacities due to the environmental along with economic constraints to emerge a new generating plants and transmission lines [2] [3]. Power flow in the lines and transformers shouldn't be allowed to raise into a level in which a haphazard occurrence might lead to the actual system fall down as cascaded breakdowns [4] [5]. With regard to managing the power transmission system, Flexible Alternating Current Transmission System (FACTS) is often a better device that's utilized [6-7]. FACTS is regarded "an electric power automated dependent process along with other fixed device in which present management of a number of AC transmission system parameters to build up controllability in addition to magnify power transfer capability" [8]. The actual several types of FACTS devices available for this function contains Static Var Compensator (SVC), Thyristor controlled series Capacitor (TCSC), Static Synchronous series compensator (SSSC), Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC) and Interlink Power Flow Controller (IPFC) [9]. UPFC is probably the best FACTS devices which can control both active and reactive power flow in transmission line. [10].

The optimum position of UPFC device permits to manage its power flows for an interconnected system, and thus to raise the system load ability [11]. Various kinds of optimization algorithms are used to solve this

sort of issue, for example genetic algorithms, reproduced annealing, tabu search and etc. [12].

This paper proposes a heuristic method for minimizing power loss in the power system using UPFC. The novelty of the proposed method is to use the Bat algorithm to find optimal location UPFC under generator outage conditions. When the generator outage occurs, which in turn affects the power flow constraints like voltage, power loss, real and reactive power? For improving the system performance, UPFC is placed in the optimum location given by Bat algorithm. The objective of this paper is to reduce the power loss. The rest of the paper is organized as follows: Recent research works are discussed in section 2. Section 3 deals with UPFC structure, problem formulation and Heuristic algorithm. Section 4 gives the results and section 5 concludes the paper.

## 2. RECENT RESEARCH WORK: A BRIEF REVIEW

Number of similar performs are available in literary works, which dependent on improving the power transfer ability to electrical power process. Some of them are usually assessed here.

Mark Ndubuka Nwohu[13] presented an approach to find and choose the optimal location of Unified Power Flow Controller (UPFC) based on the sensitivity of the total system active power loss with respect to the control variables of the Unified Power Flow Controller (UPFC). The control system of the UPFC's injection model is developed and its contributions to avoiding a

voltage collapse are explored by analyzing a multi-machine test system.

Seyed Abbas Taher et al. have got introduced this demands connected with hybrid immune algorithm to have the optimum location of UPFCs for attaining minimum total active and reactive power production cost of generators and reducing the installation cost of UPFCs [14]. They executed simulations upon IEEE 14-bus and 30-bus test system.

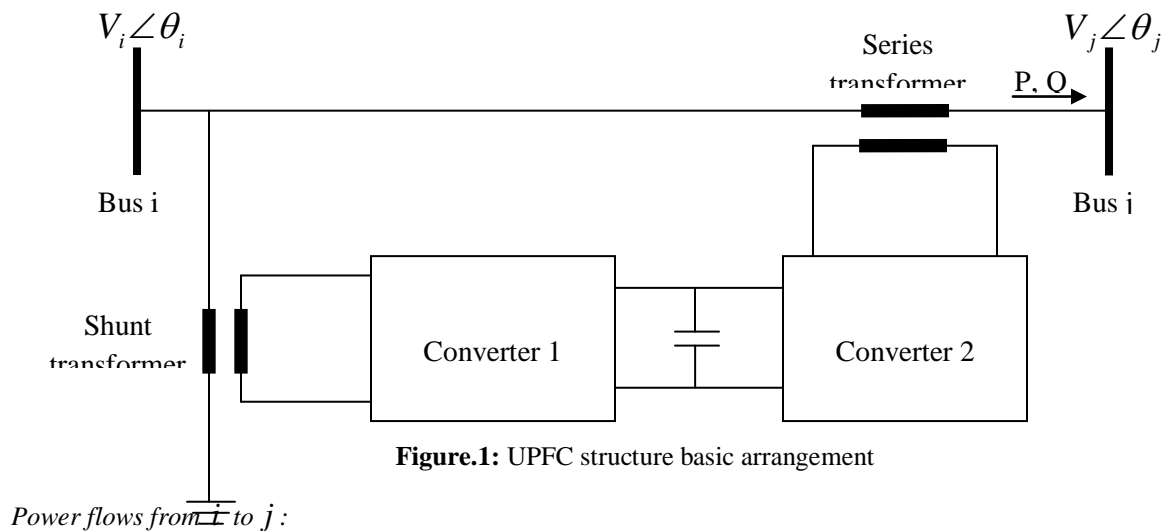
Farangfar et al. [15] used, the UPFC injection model and investigated its effect on load flow and loss reduction in power systems. In this study, the Newton-Raphson algorithm is modified to consider the benefits of having a UPFC in the power system. Simulations have been implemented in MATLAB and the IEEE 14-bus system has been used as a case study.

Chuan Wang et al. [16] have planned a new hybrid topology scale-free Gaussian-dynamic particle swarm (HTSFGDPS) optimization algorithm for real power loss minimization problem of power system. Many people focus on a new combination of swarm intelligence optimization theory and complex network theory, as well as its application to electric power system.

B.Vijay kumar *et al* have attempted the problem of optimal location of UPFC to minimize power loss of power system using Artificial Bee Colony algorithm [17]. They were carried out simulation studies on IEEE 30 bus system.

### 3. POWER SYSTEM MODEL WITH UPFC

The UPFC (unified power flow controller) is a FACTS device able to control simultaneously active power flows, reactive power flows and voltage magnitude at the UPFC terminals. UPFC consist of two voltage source converters, i.e., converter 1 and converter 2, connected back to back through a common DC link provided by a DC storage capacitor. The converter 1 is a shunt connected voltage source converter, which is used to generate or absorb controllable reactive power and shunt reactive compensation for the line [18]. The converter 2 performs the main function of UPFC by bringing in an AC voltage with magnitude that can be controlled and the phase angle is in series with the transmission line through a series transformer. The necessary reactive power is supplied or absorbed locally by converter 2 and active power is replaced as a consequence of the series injection voltage [18,19]. The UPFC structure basic arrangement between  $i$  and  $j$  bus is described in the following figure 1.



$$P_{ij}(t) = (V_i^{2(t)} + V_{kl}^{2(t)})G_{ij}^{(t)} + 2V_i^{(t)}V_{kl}^{(t)}G_{ij}^{(t)}\cos(\alpha_{kl} - \phi_j) - V_j^{(t)}V_{kl}^{(t)}[G_{ij}^{(t)}\cos(\alpha_{kl} - \phi_j) + b_{ij}^{(t)}(\sin \alpha_{kl} - \phi_j)] - V_i^{(t)}V_j^{(t)}(G_{ij}^{(t)}\cos \phi_{ij} + b_{ij}^{(t)}\sin \phi_{ij}) \quad (1)$$

$$Q_{ij}(t) = -V_i^{(t)}I^{(t)} - V_i^{2(t)}(b_{ij}^{(t)} + B/2) - V_i^{(t)}V_{kl}^{(t)}[G_{ij}^{(t)}\sin(\alpha_{kl} - \phi_i) + b_{ij}^{(t)}(\cos \alpha_{kl} - \phi_i)] - V_i^{(t)}V_j^{(t)}(G_{ij}^{(t)}\sin \phi_{ij} - b_{ij}^{(t)}\cos \phi_{ij}) \quad (2)$$

Where,  $G_{ij} + jb_{ij} = \frac{1}{R_{ij} + jX_{ij}}$ ,  $V_i$  and  $V_j$  are the voltage of the buses  $i$  and  $j$  and  $V_{kl}$  is the voltage of the compensating device,

The above equations power flow equations of UPFC. Initially the system is in stable condition and whenever the generator outage occurs, the power flows of the system are disturbed. This causes increase in power loss. The increased power loss can be reduced by connecting UPFC at the optimum location, which is given by Bat algorithm. The required objective function and the constraints are described in the following section 3.1.

### 3.1 Determination of optimal location of UPFC using Bat algorithm

This section describes about the determination of the UPFC location using bat algorithm. The bat algorithm is the heuristic search optimization algorithm, which works based on the echolocation behavior of bats [20]. Here, the Newton Raphson (N-R) method is used for the load flow analysis of the IEEE standard bench mark system. Then the generator outage is introduced in the system, during this time the bat-inspired algorithm is used to find the optimum location. At the beginning, the input micro-bats like voltage at each bus and the power loss are initialized, which is given in the following equation (3).

$$B_i = [(V_1, P_{L1})^1, (V_2, P_{L2})^2, (V_3, P_{L3})^3 \dots (V_n, P_{Ln})^n] \quad (3)$$

Where,  $B_i$  is the micro-bats. The input bus voltage is randomly generated with the required  $n$  dimensions search space. Here, each micro-bat have the velocity

vector ( $v_i$ ) and position vector ( $x_i$ ) and echolocation parameters like frequency ( $f_i$ ), pulse rate ( $r_i$ ) and the loudness parameters ( $l_i$ ), which are given in the following equation (4), (5) and (6).

$$f_{\min} \leq f_i \leq f_{\max} \quad (4)$$

$$r_{\min} \leq r_i \leq r_{\max} \quad (5)$$

$$l_{\min} \leq l_i \leq l_{\max} \quad (6)$$

Here, we assign the frequency range  $f_{\min} = 0$  and  $f_{\max} = 1$ , the pulse rate minimum value is  $r_{\min} = 0.5$  and the loudness maximum value is  $l_{\max} = 1$ . The remaining values are determined by the

$$l_{\min} = \frac{1}{\sqrt{n_{\text{sec}}}} \text{ and } r_{\max} = 1 - \frac{1}{n_d} \leq 1 \quad (7)$$

Where,  $n_{sec}$  is the number of sections in the discrete set used for sizing the design variable and  $n_d$  is the number of discrete design variables. Then the objective function is evaluated, using the following equation (8).

$$P_{loss} = \sum_{k \in N_E} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos \theta_{ij}) \quad (8)$$

The current populations of micro-bats are randomly updated based on the frequency and the velocity. The frequency and the velocity calculation are explained in the following equation (9).

$$f_i^t = f_{min} + (f_{max} - f_{min})u_i \quad (9)$$

Where,  $u_i$  is the random number of values, which is selected from 0 to 1, then the frequency is applied into the velocity equation, which can be described in the following.

$$v_i^t = \text{round} [v_i^{t-1} + (X_i^{t-1} - X_{\psi})u_i] \quad (10)$$

Where,  $v_i^t$  and  $v_i^{t-1}$  are the velocity vectors of the micro-bats at the time steps  $t$  and  $t-1$ ,  $X_i^t$  and  $X_i^{t-1}$  are the position vectors of the micro-bats at time steps  $t$  and  $t-1$ ,  $X_{\psi}$  is the current global best solution. Here after the local search is performed in the randomly selected population that is described in the following equation (11).

$$x_i^t = x_i^{t-1} + \xi_{i,j} l_{avg}^t \quad (11)$$

Where,  $\xi_{i,j}$  is a random number between  $-1$  and  $1$ ,  $l_{avg}^t$  is the average value of loudness at time step  $t$ . Then find the fitness of the new micro-bats using equation (9) and improve the echolocation parameters.

$$l_i^t = a.l_i \text{ and } r_i^{t+1} = r_{max} [1 - \exp(-\gamma)] \quad (12)$$

Where,  $l_i^t$  and  $l_i$  are the previous and updated values of the loudness,  $r^{t+1}$  is the pulse rate of the micro-bats in time step,  $a$  and  $\gamma$  are the adaptation parameters of the loudness and pulse rate. Then the steps to find the optimum location are described below.

#### Steps to find the optimum location

**Step 1:** Initialize the micro-bats are randomly generated at N dimension. Here, the bus voltage and line losses are the input micro-bats.

**Step 2:** Evaluate the objective function for the random number of the micro-bats.

**Step 3:** The solutions are separated into two groups, the first groups have the minimum best solutions and another group has maximum best solutions.

**Step 4:** Find the best solution according to the objective function and store the current population.

**Step 5:** Randomly update the current micro-bats population to update position vector and velocity vector of the micro-bats.

**Step 6:** Evaluate the objective for the new micro-bats population and select the best solution among the solution.

**Step 7:** Find the power loss, voltage, real and reactive power flow of the best solution.

**Step 8:** Check the termination criterion. If it is satisfied terminate or else go to step 9.

**Step 9:** Generate the new agents to generate new solutions. Go to Step 2.

Once this process is finished, the system is ready to give the optimum location to place the UPFC.

## 4. RESULTS AND DISCUSSION

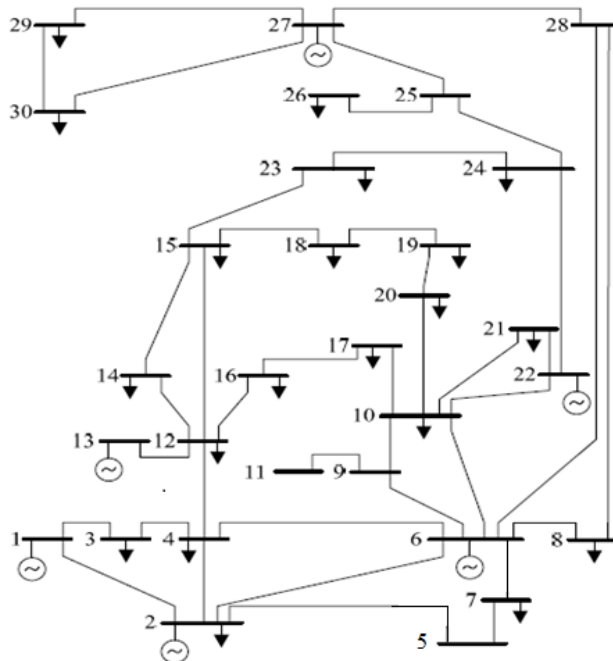
The proposed hybrid method is implemented in MATLAB/Simulink 7.10.0 (R2012a) platform, 4GB RAM and Intel(R) core(TM) i5. Here the IEEE 30 bus system is used to validate the proposed method. The numerical results of the proposed method are presented and discussed in this section. The effectiveness of the proposed method is analyzed by comparing with ABC

algorithm. Results are discussed in the following Section 4.1.

**4.1. Testing of IEEE 30 bus system**

In the section, the performance analysis of proposed method when applied to IEEE 30 bus system is discussed. Figure 2 gives the layout of the IEEE 30 bus system. It consists of 6 generator buses, 21 load buses and 42 transmission lines. Initially, normal load flow in the IEEE 30 bus system is analyzed using N-R load flow analysis. Consequently, generator outages such as

single generator outage and double generator outage are arbitrarily introduced in the generator buses, 1, 2, 6, 13, 22 and 27. Such generator outages cause disturbance in power flow and which further causes increase in power loss the system. Table 1 gives the details of power flow under normal condition, single generator outage condition and after connecting UPFC at optimum location given by bat algorithm. The power loss comparison at different conditions is given in Table 2. It shows the dominating performance of the proposed method. The proposed method effectively reduces the power loss under single generator outage condition.



**Figure.2:** IEEE 30 bus system structure

**Table.1:** Power flow analysis at single generator outage using the proposed method

Generator bus no.	Best location		Power flow					
			Normal		Generator outage		After connecting UPFC at optimum location given by bat algorithm	
	From bus	To bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
2	2	4	27.410	3.121	26.387	3.708	27.699	4.220

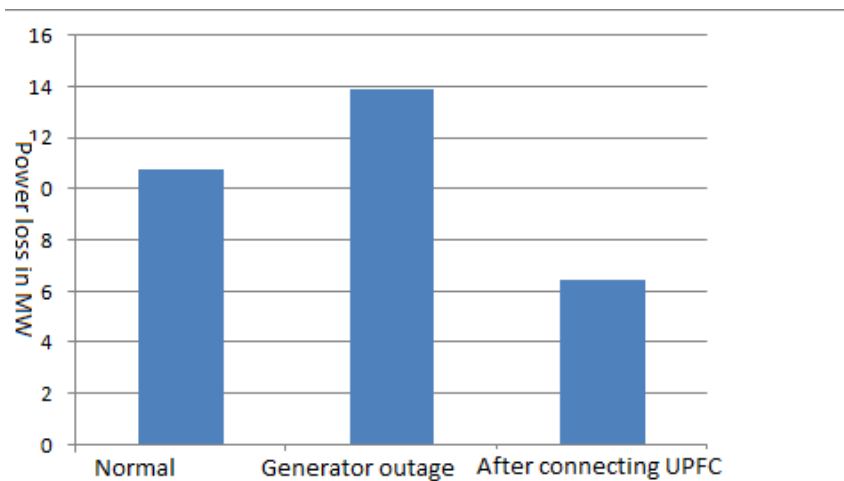
6	8	28	2.971	1.398	1.963	1.3691	5.104	0.839
13	12	16	9.529	4.077	5.564	4.766	10.835	9.409
22	24	25	1.453	3.584	1.380	1.404	3.186	6.9701
27	10	22	4.046	6.617	0.6402	4.803	4.359	8.549

From the table it is observed that normal power loss of the IEEE 30 bus system is 10.809 MW. It may rise to 13.211 MW, when there is a single generator outage problem. The increased power loss can be reduced to

6.445 MW by connecting UPFC at optimum location given by proposed algorithm. This shows the effectiveness of the proposed method.

**Table.2:** Power loss at single generator outage using the proposed method

Generator bus no.	Best location		Power loss in MW		
	From bus	To bus	Normal	Generator outage	After connecting UPFC at optimum location given by bat algorithm
2	2	4	10.809	13.912	6.445
6	8	28		13.724	6.434
13	12	16		12.795	6.460
22	24	25		13.119	6.400
27	10	22		13.211	6.445



**Fig.3** Power loss comparison at single generator outage condition

Subsequently, double generator outage is introduced in the IEEE 30 bus system. At this instant, the power flow of the system is affected. Table 3 gives the details of power flow under normal condition, double generator outage condition and after connecting UPFC at

optimum location given by Bat algorithm. Similarly Table 4 gives the power loss comparison under normal condition, double generator outage condition and after connecting UPFC at optimum location given by Bat algorithm. From the table it is observed that normal

power loss of the IEEE 30 bus system is 10.809 MW. It may rise to 16.107 MW, when there is a double generator outage problem. The increased power loss can be reduced by connecting UPFC at optimum location

given by proposed algorithm. This shows the effectiveness of the proposed method. Figure 3 and Figure 4 shows the power loss comparison at different conditions.

**Table.3:** Power flow analysis at double generator problem using the proposed method

Generator bus no.	Best location		Power flow					
	From bus	To bus	Normal		Generator outage		Proposed method	
			P	Q	P	Q	P	Q
			(MW)	(MVAR)	(MW)	(MVAR)	(MW)	(MVAR)
2 and 6	6	7	47.479	2.110	44.327	1.292	46.898	3.715
2 and 13	12	15	19.674	7.796	14.813	8.708	24.454	7.528
6 and 13	12	15	19.674	7.796	16.202	8.216	20.936	3.666
22 and 27	10	20	7.665	3.278	6.801	3.866	8.722	3.762
13 and 27	5	7	23.744	13.824	17.948	11.419	26.427	20.810

**Table.4:** Power loss at double generator problem using the proposed method

Generator bus no.	Best location		Power loss in MW		
	From bus	To bus	Normal	Generator outage	Proposed method
2 and 6	6	7	10.809	16.015	6.4546
2 and 13	12	15		15.017	6.4319
6 and 13	12	15		16.107	6.4691
22 and 27	10	20		14.367	6.7079
13 and 27	5	7		15.264	6.4311

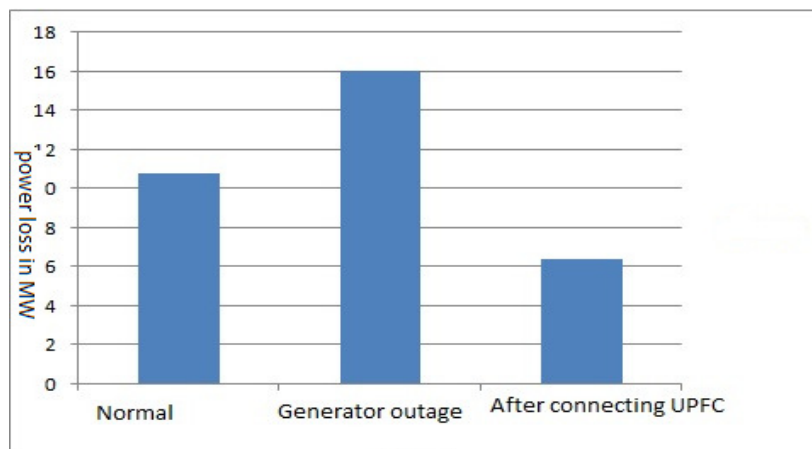


Fig.4 Power loss comparison at double generator outage condition

## 5. CONCLUSION

This paper describes about minimization of power loss by optimal location of UPFC given by the bat algorithm. By connecting UPFC at the optimum location, and the power flow has been analyzed. The advantage of the proposed method is capability and robustness to solve the complex optimization problem. In the results, system power flows, power loss was analyzed. The comparison of results proved that the proposed method is the most effective technique to reduce power loss of the power system, which is competent over the other techniques.

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